UNIVERSITI PUTRA MALAYSIA

FABRICATION AND CHARACTERIZATION OF SOME NiZn-BASED FERRITE MULTILAYER INDUCTORS (MLIS)

LUCIA LIEW WOAN SHYAN

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MASTER OF SCIENCE
UNIVERSITI PUTRA MALAYSIA

2000

FABRICATION AND CHARACTERIZATION OF SOME NiZn-BASED FERRITE MULTILAYER INDUCTORS (MLIS)

By

LUCIA LIEW WOAN SHYAN

Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Science Universiti Putra malaysia

September 2000

DEDICATIONS

To

Dear Mom and Dad, brothers and sisters

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

FABRICATION AND CHARACTERIZATION OF SOME NiZn-BASED FERRITE MULTILAYER INDUCTORS (MLIS)

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September 2000

Chairman: **Associate Professor Mansor Hashim, Ph.D.**

Faculty: **Institute of Advanced Technology**

The multilayer inductor is particularly important as a highly stable, easy to use and miniaturised component in electronic systems, such as radios, VCRs and computers. There were two main tasks in this research project, one was to make a proper preparation set-up, and the other was to measure the inductance and the reciprocal of the Q factor of the multilayer inductors produced. Layers of ferrite sheets were stacked together with silver layers in between by means of tape casting method. End metallization was applied to make contact with the inner conductors. Bulk and multilayered components of the same dimension were made to undergo parallel conventional sintering. The experimental work resulted in the complete construction of a tape-casting set-up. The measured L values were in the range of 10^{-1} to 10^{5} Henries and L fell rapidly with frequency from 1kHz to 30MHz. The energy was represented by

$1/Q$ ranged from 10^{-3} to 10 and also fell rapidly within the same frequency range.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

PEMBENTUKAN DAN PENCIRIAN INDUKTOR PELBAGAI LAPISAN (MLIS) FERIT NiZn

Oleh

LUCIA LIEW WOAN SHYAN

September 2000

Pengerusi: **Profesor Madya Mansor Hashim, Ph.D.**

Fakulti: **Institut Teknologi Maju**

Induktor multi lapisan adalah penting terutamanya sebagai komponen berkestabilan tinggi, mudah digunakan dan bersaiz amat kecil dalam sistem elektronik seperti radio, VCR dan komputer. Ada dua objektif utama dalam kerja peyelidikan ini. Salah satu daripadanya ialah penyediaan satu set alat yang sesuai untuk pengeluaran komponen pelbagai lapisan, manakala yang satu lagi ialah mengukur induktans dan salingan faktor Q induktor pelbagai lapisan yang dihasilkan. Lapisan ferit diletakkan berselang-seli dengan lapisan perak. Hujung susunan ini dikemaskan dengan meletakkan lapisan perak untuk dijadikan konduktor. Toroid dan komponen pelbagai lapisan disinter bawah keadaan pembakaran selari. Kerja ujikaji ini menghasilkan suatu binaan lengkap peralatan tuangan-pita. Nilai L yang diukur berada dalam julat 10^{-1} ke 10^{5} henry dan L menyusut cepat dengan frekuensi daripada 1kHz to 30MHz.

Kehilangan tenaga yang diwakili oleh 1/Q berada dalam julat 10^{-3} ke 10; ia juga menyusut cepat dengan frekuensi dalam julat yang sama.

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I certify that an Examination Committee met on 28 September 2000 to conduct the final examination of Lucia Liew Woan Shyan on her Master of Science thesis entitled "Fabrication And Characterization Of Some NiZn-based Ferrite Multilayer Inductors (MLIs)" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Science.

KAMIS AWANG, PhD
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Date: 11 JAN 2001

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

LUCIA LIEW WOAN SHYAN

Date : 23-11-2000

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LIST OF SYMBOLS AND ABBREVIATIONS

A	cross sectional area
B	induction
$\mathbf{B}_s$	saturated induction
D_i	inner diameter
D_o	outer diameter
f	frequency
h	hour
H	applied field
$\mathbf{H}_c$	coercive force
H_K	saturated anisotropy field
K	anisotropy energy
L	inductance
L / l	length
$\mathbf{M}_s$	saturation magnetisation
N	number of wire turns
PVA	polyvinyl alcohol
Q	quality factor
RLF	relative loss factort
tan δ	loss tangent
T	thickness

W	width
XRD	X-Ray Diffraction
μ	magnetic moment
μ_B	Bohr magneton
μ_o	permeability of free space
μ	permeability
μ_i	initial permeability
μ'	real part of permeability
μ''	imaginary part of permeability or magnetic loss
ρ	resistivity
γ	Gyromagnetic ratio
ω	angular velocity
σ	internal stress
λ	magnetostriction

CHAPTER I

INTRODUCTION

Ferrites

Ferrites are magnetic ceramic materials, containing mostly iron which is derived from $Fe^{2+}O.Fe^{3+}_{2}.O_3$, and mix with other oxides and carbonates in powdered form, arranged in such a manner to produce spontaneous magnetisation (Gerald, 1975; Standley, 1972; Crangle, 1991). There are soft ferrites as well as hard ferrites. Soft ferrites become magnetised by relatively low-strength magnetic field. When the applied field is removed, they returned to a state of relatively low residual magnetism, whereas hard ferrites need high magnetising field and high remnant magnetism to become magnetised. Since the pioneering works of Snoek (1936) and Takei (1939), a very large number of studies have been published by other ferrite scientists, and have generated a wide range of technological applications (Snelling). In recent years, the rapid developements in the electronic and electric industries, have created even larger and dynamic changes on the demands for the uses of ferrites.

Ferrites are ferrimagnetic materials which have domain structures and hysteresis loops, similar to those of ferromagnetic materials. They have three distinct crystal structures: the hexagonal magnetoplumbite, dodecahedral garnet and the spinel structure (Crangle, 1991; Standley, 1972). Hexagonal magnetoplumbite is a hard ferrite structure, dodecahedral garnet and the spinel are soft ferrite structures. Soft ferrites are used for applications in which the material must be easily magnetised and demagnetised such as cores for power transformers, small electronic transformers etc. On the other hand, hard magnetic materials are used for applications requiring permanent magnets which do not demagnetise easily such as the permanent magnets in loudspeakers, telephone receivers, and automotive starting motors. Anyway, it is the soft ferrites that are of concern in this research project.

Nickel Zinc Ferrite

The type of ferrite which is used in this research work is Nickel Zinc (NiZn) ferrite. It was developed for a wide range of applications where high permeability and low loss were the main requirements. NiZn ferrite is still one of the most important ferrites for such applications and constitutes a substantial portion of present day soft ferrite production. NiZn ferrites have been extensively used as core materials for large number of devices and electrical components such as inductors, transformers, antenna rods etc.

Some Magnetic Parameters

One of the most important parameters in magnetic materials evaluation is the permeability. Permeability is an extrinsic property and can be defines as ratio of induction, B to the magnetizing field H.

$$\mu = \frac{B}{H}$$

Permeability can also be written in complex form, where the real part μ' showed the energy stored, expressing the component of B in phase with H and the imaginary part μ'' indicating the energy dissipated, expressing the component of B out of phase with H.

$$\mu = \mu' - j\mu''$$

The permeability concept can be extended to include the losses. For time harmonic fields,

$$H = H_o \exp(j\omega t)$$

where ω is the angular frequency and t is the time. The dissipation can be described as the phase difference between H and B, δ. In the complex notation, the frequency dependency of permeability becomes

$$\mu(\omega) = \frac{B \exp j(\omega t + \delta)}{H \exp (j\omega t)}$$

which would give us, again,

$$\mu(\omega) = \mu' - j\mu''$$

where μ'' can actually be obtained from the relation

$$\mu'' = \mu' \tan \delta$$

Permeability can not only be influenced by the chemical composition and crystal structure, but is also strongly dependent on microstructure, temperature, stress and time after demagnetization.

Multilayer Inductors

"Multi_" comes from the word "multiple" which means having many parts or elements, or a quantity which contains another quantity an exact number of times as we use in mathematics.

Multilayer chip inductors were introduced in 1987 and soon became the inductive components of choice for many design engineers. For example, Toko, a Japanese company, introduced the first microminiature multilayer chip inductor LL2012 in the year 1992. And soon it became the inductive components of choice for many design engineers.

Multilayer technology offers three advantages:

1. Monolithic structure which is good for high reliability
2. Magnetic shielding which is excellent for very high density applications
3. Low mounting cost as multilayer (chip) inductors do not require winding